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Energy Forever

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This is the second part of a two-part article.

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The world is dangerous. America's energy policy makes it more so. In 1981 we wrote for the Pentagon what is still the definitive unclassified study of domestic energy vulnerability.[1] We found, and government and industry experts later confirmed, that a handful of people could shut down three-quarters of the oil and gas supplies to the eastern states overnight without leaving Louisiana. A similar group could cut electric power to any region or kill millions by sabotaging a nuclear power plant or crashing an airliner into it. Little has changed since then. Most existing U.S. energy supplies— and the additional ones proposed in the current House energy bill—are highly vulnerable to attack.

> **Energy systems designed to be efficient, decentralized, and diversified are what national security demands, the public wants, and the market is ready to supply.**

National security is also at risk because 13 percent of the oil we use comes from the Persian Gulf (which holds two-thirds of the world's petroleum re-serves). Buying the fastest and cheapest replacements is urgent. But replacing insecure foreign oil with insecure new domestic energy sources doesn't help. We will have a secure supply of energy only when we have both displaced Mideast oil *and* shifted the basic architecture of our domestic energy infrastructure. Energy systems don't become secure by being located in this country—unless widespread failures are made impossible and local failures benign.

Consider the current fixation on drilling for oil in the Arctic National Wildlife Refuge.[2] The 800-mile-long Trans-Alaska Pipeline System (TAPS), the only way to ship Refuge oil south, presents such a fat terrorist target—worse than the Strait of Hormuz choke point—that former CIA Director R. James Woolsey, a normally oil-favoring Oklahoman, testified against Refuge oil as too vulnerable.[3] TAPS is not only accessible to attackers; it's often unrepairable in winter. If key pumping stations or facilities at either end were disabled, at least the aboveground half of the pipeline's nine million barrels of hot oil could congeal in one winter week into the world's largest Chap Stik. The Army, the U.S. General Accounting Office, and the Senate

Judiciary Committee have said that TAPS is indefensible. It has already been incompetently bombed twice, sabotaged, and shot at on more than 50 occasions. On October 4, 2001, a drunk's rifle shot pierced it, interrupting one-sixth of U.S. oil output for 60 hours. Two years ago, a disgruntled engineer's sophisticated plot to profit from oil futures trading was luckily thwarted before he blew up three critical TAPS sites.[4] Senators who have made Refuge oil the centerpiece of their whimsically titled National Energy Security bill have obviously not connected the dots.

The 24-year-old TAPS also suffers from corrosion, erosion, stress, and melting of the supporting permafrost—all raising maintenance costs, which may become unaffordable within this decade. Management deficiencies also persist. In 2000, TAPS suffered two serious accidents and its Valdez oil terminal narrowly escaped another. On September 22, 2001, for the seventh year in a row, a botched routine procedure overpressurized the pipeline, causing spills at three pumping stations. Even in a terrorist-free world, extended reliance on TAPS would be imprudent.

Fortunately, there are faster, cheaper, and surer alternatives. We can achieve energy security by using less energy far more efficiently to do the same tasks—and then by supplying what is still needed from sources that are inherently invulnerable because they're dispersed, diverse, and increasingly renewable. These options reduce the need to transport energy by vulnerable long-distance pipelines and transmission lines, and usually cost much less than expanding those links.[5]

Security at a Profit

In the case of tasks now reliant on oil, the change would be relatively easy. Energy efficiency is the rapid-deployment resource, and huge amounts of it are available. Just a 2.7-mpg gain in the fuel economy of this country's light-vehicle fleet could displace Persian Gulf imports entirely[6], and this is no pipe dream. The National Academy of Sciences reported last year that the fuel economy of conventional cars and light trucks could be raised vastly more than that without compromising safety, performance, or affordability.[7] Similarly, the Defense Science Board recently showed how the Pentagon—the world's largest oil buyer and the nation's largest energy user—could save billions of dollars' worth of fuel annually while greatly improving its war-fighting capability.[8] Efficiency is an energy resource that is uninterruptible and already delivered, immune to both foreign potentates and terrorism. It also stabilizes prices, protects climate and environment, and provides good jobs nationwide.

As for new fuels to replace oil, we already know how to produce them cost-effectively from renewable sources. Farm, forest, industrial, and urban wastes and certain soil-replenishing crops can yield clean transportation fuels, fertilizer, and substitutes for petrochemicals (often with heat and electricity as convenient by-products).[9] If these are produced near where they're used, giant refineries and vulnerable pipelines can be bypassed. Done right, the use of such biofuels would also -spread jobs, preserve rural culture, enrich topsoil, enhance farm income, and protect global climate.

Coherent policies to mobilize these secure and proven resources, best buys first, could displace insecure foreign *and* domestic oil promptly and profitably.

Supplying secure and affordable electric power is similarly feasible. America's electricity comes mainly from big power plants that stopped getting more efficient in the'60s, cheaper in the'70s, bigger in the '80s, and built in the '90s. The ones we already have will continue to serve us for a long time, however, and should at least start reusing the waste heat they now throw away—as much energy as Japan consumes for everything. In principle that could cut America's total fuel usage by one-third, halve net generating cost, and save a trillion dollars per decade if more regulators allowed it here as they do in Europe.[10] But big power stations can't supply really cheap and reliable electricity, for two reasons: The power delivery systems cost even more than the stations, and the grid causes almost all the power failures.

Onsite and neighborhood micropower generated in or near customers' premises can solve both problems, offering diverse, decentralized, and thus nearly invulnerable supplies of electricity. Because microgeneration is also more flexible and quickly built than large power plants—and it benefits from the valuable financial and engineering advantages of electric sources that are the right size for the job[11]—it is favored in the market as well.

Doubled-efficiency, combined-cycle, gas-fired power stations, each producing hundreds of megawatts, swept the market in the 1990s. Now becoming obsolete, they're starting to be displaced by swarms of microturbines, engine generators, and fuel cells that are a thousand or even ten thousand times smaller but equally or more efficient (and can more easily recapture waste heat). Manhattan's Condé Nast Building, for instance, was designed to use half the energy of an ordinary office building; and with the saved construction costs, the developers were able to equip it with the two most reliable known power sources—fuel cells and solar cells. This ultrareliable on-site electricity helped them win in the real-estate market by recruiting premium tenants quickly at premium rents.

Dispersed, renewable electricity sources are the fastest-growing in Europe. Local windmills already provide 18% of Denmark's power and are on track to provide half in 2030. In fact, wind power has lately added more megawatts worldwide than nuclear power averaged throughout the 1990s, and it dominates Europe's plan to make 22 percent of its electricity from renewables by 2010 (twice today's U.S. fraction).[12] According to government experts, wind power could cost-effectively more than meet all of the world's electricity needs—or America's—at constant prices now edging below 3 cents per kilowatt-hour. Solar power is enjoying a similar boom, lately growing 26 percent to 42 percent a year. In Sacramento five tract developers offer, as standard equipment, house roofs that make solar electricity. (After a referendum shut down the troubled nuclear plant that had provided nearly half Sacramento's power, investments in efficiency and new, diverse, and often decentralized and renewable supplies replaced it reliably at lower cost. Moreover, university analysts found that five years' investments in electric efficiency had boosted county economic output by $185 million and added 2,946 employee-years of net jobs.[13]) Around the country, leading home builders are planning hundreds of grid-linked solar-powered sub-divisions.[14]

The benefit to national security is not what sells micropower. Yet as Assistant Secretary of Energy David Garman says[15], "Aside from its obvious environmental benefits, solar and other distributed energy resources can enhance our energy security." Garman adds:

> Distributed generation at many locations around the grid increases power reliability and quality while reducing the strain on the electricity transmission system. It also makes our electricity infrastructure less vulnerable to terrorist attack, both by distributing the generation and diversifying the generation fuels. So if you're engaged in this effort, it is my view that you are also engaged in our national effort to fight terrorism.

Meanwhile, micropower's explosive growth further raises the financial risk of building big (and vulnerable) power plants, because fast and agile competitors can idle them even before they're finished.[16] In the mid-1980s, California shifted from power scarcity to glut in just two years by deploying efficiency and decentralized supplies. In 2001 it took only half a year—and the efficiency and micropower installers are still back-ordered.

Efficiency and micropower are natural partners. With very efficient use of electricity, a new house can run on so few solar cells that they cost less than connecting to the grid, let alone paying subsequent utility bills. In our own house, high in the Rocky Mountains, such efficiency saved 99 percent in space- and water-heating energy, cut electricity use by 90 percent, and paid for itself in 10 months—all with 1983 technology.[17] Other people have built houses that are comfortable with no air conditioning at up to 115 degrees Fahrenheit yet cost less to construct than conventional houses.[18] Such large reductions in the energy needed make micro-generation particularly attractive and will speed its spread.

Integrated, superefficient design is the crucial factor. It can often make very large energy savings cost *less* than small or no savings. That's been demonstrated in a wide range of technical systems, uses, and economic sectors. In a typical industrial pumping loop, for example, an improved design cut power use by 92 percent, cost less to build, and worked better. This was achieved not by any new technology but solely by better design that used fat, short, straight pipes rather than skinny, long, crooked ones. It's not rocket science—just good Victorian engineering rediscovered.[19]

Fast-Forward to Hydrogen

The next step will integrate efficiency with a shift from hydrocarbons to plain hydrogen. We've already made progress in reducing the carbon burning that harms the climate; today, two of every three fossil-fuel atoms we burn are hydrogen, the other one carbon. The emerging hydrogen economy eliminates both the burning and the rest of the carbon by using pure hydrogen in fuel cells. Remember the high-school chemistry experiment in which an electric current splits water into hydrogen and oxygen? A fuel cell reverses this process, chemically recombining these gases to produce electricity, pure hot water, and nothing else. Fuel cells are the most efficient, clean, and reliable known source of electricity.

Initially, the hydrogen that they need will be made mainly from natural gas, but that's no obstacle. An already mature hydrogen industry has developed ways to do this economically at all scales, though smaller is often cheaper as well as less vulnerable.[20] Hydrogen is cost-competitive today in many uses. Moreover, the buoyant, clear-flame gas is safer to use and store than gasoline[21], and new research suggests that its refueling infrastructure would be cheaper.[22]

Nor is there need to worry about the natural gas running out: Even as the hydrogen economy grows, it will probably use less natural gas than we do now. In the long run, hydrogen will most likely be made from water, using renewable electricity or possibly just sunlight. Or it may be extracted from oil and perhaps even coal[23], without releasing the carbon into the air. All these options are evolving rapidly and will compete vigorously.

Energy isn't secure just because supplies are located in this country; we must also make widespread energy failures impossible and local failures benign.

This isn't science fiction; speeded by micropower's special economic benefits[24], it's already starting to happen. Hundreds of U.S. buildings, from New York's Central Park police station to an Omaha credit-card data center, are powered by fuel cells. Fuel-cell buses are on the market. Experimental fuel-cell-powered cars are on the road, and Energy Secretary Spencer Abraham announced on January 9 a federal–Big Three co-elaboration to speed them to market. The heads of seven major oil and car companies have announced the start of both the Oil Endgame and the Hydrogen Era—a more profitable venture in which they're strongly investing.[25] In Royal Dutch/Shell's latest planning scenarios, the business-as-usual case has the world getting one-third of its energy and all its increased energy from renewable sources by 2050; the other, more radical scenario envisages an accelerated shift to hydrogen, with oil use stagnant until 2020 and falling sharply thereafter.[26] Ex-Saudi Oil Minister Sheikh Yamani is the latest of several energy experts to say that "the Stone Age did not end because the world ran out of stones, and the Oil Age will not end because the world runs out of oil."

Hypercars

The efficiency revolution's latest surprise squarely targets oil's main users and its dominant growth market: cars and light trucks. New American cars average 24 mpg, a 20-year low. But an industrywide transition is under way.[27] Toyota's Corolla-class Prius hybrid-electric five-seater gets 48 mpg; Honda's CRX-class two-seat hybrid, 64 mpg. A car fleet as efficient as the Prius would save 25 Arctic Refuges, but it's just the start. Ford, DaimlerChrysler, and General Motors are already testing family sedans at 72 mpg to 80 mpg. Almost every automaker at the recent Tokyo Auto Show displayed good hybrid-electric prototypes, some getting more than 100 mpg. Volkswagen already sells Europeans a 78-mpg, four-seat nonhybrid subcompact and plans a two-seat city car for 2003 that will get 235 mpg (not a typo; VW is even testing a diesel version that gets the equivalent of 282 mpg). When cars are so fuel-frugal, powering them with fuel cells becomes a near-term option using current technology.

In 2000, Hypercar, Incorporated (www.hypercar.com), a firm previously spun off from our Rocky Mountain Institute[28], designed a manufacturable, competitive-cost, midsize-SUV concept car. Supercomputers show it's as roomy, comfortable, and sporty as a Lexus RX-300 or a Ford Explorer[29]—and as safe even if it hits one, although both are twice its weight.[30] (The car's structure is made of ultra-light carbon-fiber composite, which can absorb up to five times more crash energy per pound than steel.) Getting the equivalent of 99 mpg, it would drive 330 miles on 7.5 pounds of safely stored compressed hydrogen, or about 600 miles on 14 pounds using the latest tanks, because of the fuel cell's doubled efficiency and the car's lightness and low drag: Driving at 55 mph would use no more power than a normal SUV needs just for its air conditioner. Such superefficiency and a radically simplified, software-rich design make the car ready for the hydrogen, with fuel cells small enough to be affordable and hydrogen tanks small enough to fit.

Hypercars™ could transform the world's trillion-dollar auto industry within two decades. For the United States, such vehicles in all shapes and sizes could ultimately save eight million barrels of crude oil per day. It's like finding an inexhaustible Saudi Arabia by drilling in the "Detroit Formation." A global Hypercar fleet could save as much oil as OPEC now sells.

Such cars should do an end run around the trench warfare between advocates of high gasoline taxes and supporters of stiff efficiency standards. Policy interventions to spur people to buy squinchy, sluggish, or unsafe cars won't be needed to save fuel and reduce emissions: The new cars will sell simply because they're better than current models. (Encouragingly, the popular Toyota Prius hybrid was developed, marketed, and grown to profitability with no governmental action.) In addition, the cars' manufacturers should enjoy a competitive advantage because their needs for capital, parts, space, and assembly could be as much as 10 times lower.

This potential is compelling. Since we put the basic Hypercar design into the public domain in 1993 (so nobody could patent it—like free software), about $10 billion has been committed around the world to this general line of development.

Deployment can be speeded if the development of fuel cells in cars and buildings is integrated.[31] For example, fuel-cell-powered cars can be leased initially to people who work in or near the buildings where fuel cells will by then have been installed for power generation and space-conditioning. The cars can be designed to hook up to a nearby building when parked (about 96 percent of the time). They can then buy the building's surplus hydrogen[32] and sell back the electricity that the cars' fuel cells generate—at the time and place where it's most valuable. This could well repay much of the cost of owning the car. If all cars were Hypercars of various sizes, they could ultimately provide 6 to 12 times as much generating capacity when parked as all electricity suppliers now own; they would displace the world's coal-fired and nuclear plants many times over.

Both near-term and more radical energy savings would happen faster if resources were properly mobilized and policies aligned. For example, auto buyers could be charged a fee for inefficient new cars or paid a rebate for efficient ones—the fees to pay for the rebates. The turnover of the car fleet could be accelerated if the rebate for an efficient new car were based on the *difference* in efficiency between the new car you buy and the old car you scrap. (Scrapping and not replacing it earns a bounty.) By encouraging the premature disposal of the least efficient cars, the "feebates" would create a strong economic stimulus to the auto industry. The benefits for oil imports, balance of trade, national security, air quality, climate, and equity also would be big and fast.

This is only one of many innovative policy possibilities.[33] We could also desubsidize driving, parking, and roads; let noncar vehicles, like innovative buses and bicycles, compete fairly; stop subsidizing and mandating sprawl; free up gate and slot monopolies to increase airline competition so that direct flights would replace unwanted stops in "fortress hubs"; and help heavy-truck and commercial-aircraft makers rapidly double or triple their products' fuel efficiency.

The policy menu need not be confined to an impoverished list of tax tweaks; it can be rich, diverse, expanding, and appealing to all ideological tastes.[34] Outside the transportation sector, we could be teaching architecture, engineering, and business students how to make the most of modern efficiency potential. We could make markets in saved energy, so bounty hunters would pursue it relentlessly. We could mobilize communities to install mass retrofits block by block. We could promote radically fuel-saving businesses that, instead of selling more cars and gallons, use less of both to provide convenient transportation services. We could scrap inefficient technologies as vigorously as we introduce new ones, rather than further impoverishing poor people and poor nations by selling them our cast-off junk.

This last is not a minor point. America's energy policy primarily serves her own needs, but it should also serve the world. Advanced energy efficiency and competitive renewable sources offer extraordinary leverage for helping the world's poor, especially the two billion people with no electricity, to achieve the decent life without which even today's $11,000 per second spent on weapons and warriors cannot keep us safe.[35]

Consider the example of a good compact fluorescent lamp. It emits the same light as an incandescent lamp but uses four to five times less electricity and lasts 8 to 13 times longer, saving tens of dollars more than it costs. It avoids putting a ton of carbon dioxide and other bad stuff into the air. But it does far more. In suitable numbers—half a billion are made each year—it can cut by a fifth the evening peak load that causes blackouts in overloaded Bombay, boost poor American chicken farmers' profits by a fourth, or raise destitute Haitian households' disposable cash income by up to a third. Making the lamp needs 99.97 percent less capital than does expanding the supply of electricity, thus freeing investment for other tasks.[36] The lamp cuts power needs to levels that make solar-generated power affordable, so girls in rural huts can learn to read at night, advancing the role of women. One light bulb does all that. You can buy it at the supermarket and screw it in yourself. One light bulb at a time, we can make the world safer.

Choice, Not Fate

America's energy supply industries have done a remarkable job of fueling the world's greatest economy. They are vital, skilled, dedicated, and often innovative. But energy policy is not about the past; it shapes the future. It should create a structure for treating that future as choice, not fate.

When the market vaporized the supposed energy shortages on which the Bush administration had founded and advertised its 2001 National Energy Policy plan for 1,300 to 1,900 new power plants and oil drilling everywhere, a new political opening was created. When the Kyoto Protocol to start protecting global climate was accepted by almost every other nation, potentially disadvantaging U.S. firms that can't profit from its carbon trading[37], the politics shifted further—especially given recent evidence that reducing carbon emissions can accompany economic vitality. (From 1996 through 1999, the U.S. economy grew nine times as fast as carbon emissions. The global economy in 1998 and 1999 grew 2.5 percent and 2.8 percent, respectively, while carbon emissions fell 0.5 percent and 0.8 percent.[38]) Meanwhile, nuclear power's failure in the capital market has been sealed by fears about its vulnerability to terrorism, and conservatives have joined environmentalists to oppose sweeping federal powers to override siting decisions at the state level.

This is a ripe moment to re-examine America's energy opportunities, yet Congress seems about to reach gridlock over old wish lists. Anticipating this, two nonpartisan nonprofit groups—Rocky Mountain Institute and the Consensus Building Institute—recently formed the National Energy Policy Initiative to bring together a distinguished independent group of ideologically diverse energy policy experts. They will seek consensus on the objectives, principles, and content of an energy policy that can command wide support. In February this group's recommendations will be delivered to senior political leaders and offered to all Americans.

We don't know and can't shape what those recommendations will be. However, three decades of well-documented experience world-wide suggest that both fair market competition and wise administrative decisions broadly tend to favor certain outcomes. These include more efficient use, energy of the right quality and scale for the job, flexibility, and transparency. A sound energy policy won't pick winners, bail out losers, substitute central planning for market forces, or forecast demand and then build capacity to meet it. Rather, it will bust the barriers that now prevent the market from dispassionately picking the best portfolio of investments in both efficiency and supply.

Informed consumers don't need bosses or nannies to tell them how to live their lives; instead, they should get to choose among options that compete fairly at truthful prices.[39]

Then energy demand won't grow, and this will actually help the economy. (Starting in 1975, demand for oil nationwide didn't rise for 16 years, while gross domestic product grew 63 percent; beginning in the late 1970s, per capita demand for electricity in California remained stable for 20 years, while the state's economy nearly doubled.) With stable or dropping demand—and the time this buys for building next-generation energy supplies—it will be practical to provide secure, safe, and clean energy services at least cost, for all, for ever.

Inventor Edwin Land said that people who seem to have had a new idea have often simply stopped having an old idea. The key old idea to stop having is that traditional supply-side approaches make sense or money. A new, balanced, market-driven energy policy can make both—if we gracefully let go of the past, embrace what works, and do what most Americans want.

AMORY B. LOVINS and L. HUNTER LOVINS *founded and lead Rocky Mountain Institute, advise industry and government, and have received the "Alternative Nobel," Onassis, Nissan, Shingo, and Mitchell Prizes; a MacArthur Fellowship; and the Heinz, Lindbergh, Heroes for the Planet, and World Technology Awards.*

This is the second article in a two-part series. The first appeared in the January 28, 2002 issue of *The American Prospect.* For annotated versions of that article and this one, go to www.rmi.org.

Annotations to "Energy Forever"

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[1] *Brittle Power: Energy Strategy for National Security*, Brick House (Andover MA), 1982, reposted with related readings at www.rmi.org/sitepages/pid533.php. The book documents significant attacks on energy systems then taking place every few days somewhere in the world, not counting one or two countries where they occurred more or less daily. For a brief modern update of domestic energy vulnerability, see R. Housman & D. Martin, "Protecting America's Critical Energy Infrastructure from Terrorist Attack," Nov. 2001, Bracewell & Patterson, LLP (Houston).

[2] A.B. & L.H. Lovins, "Fool's Gold in Alaska," *Foreign Affairs*, July/August 2001, posted with a heavily annotated version and updates at www.rmi.org/sitepages/pid171.php. William McKibben has written that Refuge drilling would be akin to pinning a big "Kick Me" sign on Uncle Sam's backside. The constituencies pushing for Refuge drilling nonetheless have keen interests at stake. The Alaskan Congressional delegation wants to pay for continuing the state's negative income tax (80% of Alaska's unrestricted general revenue comes from oil). Oil-service companies want to spend others' money. And operators want to expand and prolong their use of the half-idle, nearly-paid-for Trans-Alaska Pipeline System.

[3] November 1, 2001, testimony to the Energy Subcommittee of the House Science Committee. Woolsey stated he had no objections on environmental grounds.

[4] He was more benign than the September 11 attackers, whose Algerian colleagues recently threatened to blow up a huge gas pipeline to Southern Europe. Reuters and leading newspapers reported in late October, though the Attorney-General later denied, that six Middle Eastern men briefly detained in the Midwest had box-cutters and photos of TAPS.

[5] Utilities have achieved roughly tenfold capital savings by replacing transmission expansion with demand-side investments and local generation. Yet neither current nor proposed Federal laws, nor rules in most states, require that new energy-transporting facilities be shown to be the cheapest solution before they're approved and given authority to take private land by eminent domain. Least-cost investments are as vital for transporting energy as for producing it.

[6] As explained in Part One, note 9, this assumes that 2.16 times as much crude oil as gasoline is saved, because that much more crude oil is used to make the gasoline. The actual ratio is unknown and may differ. For example, during the steepest-ever decline in U.S. gasoline demand, in 1978–82, refineries' crude-oil input fell 3.58 times as much as their gasoline output (or 3.11 times if adjusted for changes in blending components). Of course, buying less crude oil shifts the world oil market's supply/demand balance rather than reducing imports from any specific country, because oil is largely fungible within the market.

[7] See www.nap.edu/books/0309076013/html/). The typical potential fuel savings found cost-effective range from about 1/5 for small cars to 1/3 for midsize SUVs or nearly 1/2 for big pickup trucks. (The study also found that light-vehicle improvements have already cut gasoline consumption by 14%— comparable to Persian Gulf imports' share of U.S. oil use.) On Jan. 17, 2002, *The Wall Street Journal* (p. A2) reported that some of the initially calculated savings had been revised modestly downward, others upward. The revisions also noted that savings available in the next 10–15 years from lighter weight and lower drag, rather than from better engines, "may have [been] underestimated." They certainly were, as noted below.

[8] *More Capable Warfighting Through Reduced Fuel Burden*, January/May 2001, summarized in the Fall 2001 *RMI Solutions* newsletter at www.rmi.org/sitepages/art7048.php; one of us (ABL) was a panel member, and estimates from the report's data that long-term savings on fuel and fuel delivery could approach $10 billion a year. See also RMI's Navy efficiency research summarized at www.rmi.org/sitepages/art7057.php.

[9] R.G. Lugar & R.J. Woolsey, "The New Petroleum," *Foreign Affairs*, Jan./Feb. 1999.

[10] T. Casten, "Power Failure," Private Power LLC, 2000 York Rd., Suite 129, Oak Brook IL 60523, 630/371-0505, fax -0673.

[11] Distributed benefits are the value-adding reductions in risks, costs, and losses, and the valuable extra services, provided by electrical resources that are the right size for the job. See A.B. Lovins *et al.*, *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*, in editing, Rocky Mountain Institute, mid-2002. It will be available at www.rmi.org.

[12] Encouraging progress is summarized in the European Environment Agency's Environmental Issues Report #27, *Renewable Energies: Success Stories* (Copenhagen), 2001. In 2001 alone, installed wind-power capacity grew by 66% in the U.S. to 4.3 billion watts, and worldwide, by 31% to 23.3 billion watts.

[13] R. Fountain, "Economic Impact of SMUD Energy Efficiency Programs," Real Estate & Land Use Institute, California State University, Sacramento, March 29, 2000 report to Sacramento Municipal Utility District, www.smud.org/info/reports/econ_impact/report2000.html. After the California power crisis, hydroelectric drought and stratospheric wholesale prices forced SMUD to raise its electricity prices on May 10, 2001, but they were still about one-third lower than neighboring PG&E's.

[14] *Builder OnLine*, Oct. 2001, reports that these include U.S. Home, Morrison Homes, Shea, Beazer, D.R. Horton, Pardee, and others. Sacramento's progress is periodically reported at www.smud.org/pv.

[15] Address to UPEx '01 Photovoltaic Conference, October 2, 2001. Secretary Garman's portfolio is efficiency and renewable energy.

[16] This year, clean microgeneration is expected to emerge in already-demonstrated "vernacular" forms—solar panels that produce AC power directly, and hand-portable fuel-cell generators—that you can buy at the lumber-yard or by mail-order and plug into any outlet to help power your house. Two-thirds of the states already let you sell back homemade power to the grid for the same price you're charged, although few yet make the interconnection cheap and simple, most builders and building inspectors don't yet know the technology, and policy still favors large scale rather than being scale-neutral.

[17] See Rocky Mountain Institute, *Visitors' Guide*, Publ. #H-1, 1991; A.B. Lovins, "If It's Not Efficient, It's Not Beautiful," *Fine Homebuilding*, p. 4, Spring 1991, RMI Publ.. #E91-10; and Ch. 5 in P.G. Hawken, A.B. & L.H. Lovins, *Natural Capitalism,* Little Brown (NY), 1999), www.natcap.org.

[18] *Id.*; "The Super-Efficient Passive Building Frontier," *ASHRAE J.*, pp. 79–81, Spring 1995, RMI Publ. #95-29; and ACT[2], www.pge.com/003_save_energy/003c_edu_train/pec/info_resource/act2_proj.shtml.

[19] Hawken *et al.*, *op. cit. supra*, Ch. 6; see also especially Chs. 2, 4–5, 9–11.

[20] If desired, to guard against disruption of the gas or electric grid supplying the onsite hydrogen appliance (reformer or electrolyzer), these supplies can be backed up onsite by propane storage or renewable electricity (to split water) or both. Because the fuel cell is about twice as efficient as a conventional power plant—three times if its waste heat is also used—the amount of backup needed is relatively modest. Storage of pre-produced hydrogen is also well-established, safe if properly done, and relatively inexpensive.

[21] This is because hydrogen is extremely light and diffusive (so it quickly rises up and away from you) and burns with a clear flame that doesn't radiate searing heat to burn you at a distance. Because hydrogen is used more efficiently, too, far less of it is stored for a given use. Contrary to myth, the *Hindenburg* disaster actually illustrates hydrogen's safety *advantages*: 35% of the dirigible's occupants were killed by the fire in the canopy and diesel oil, but the other 65% survived by riding the flaming craft to earth as the clear hydrogen flames swirled harmlessly above them. See www.HydrogenUS.com, www.eren.doe.gov/hydrogen, and www.rmi.org/sitepages/pid536.php.

[22] C.E. Thomas, "Hydrogen Infrastructure: Less Costly Than Gasoline?," Aspen Clean Energy Roundtable VII, Montreux Energy Forum, October 2001, www.h2gen.com.

[23] Encouraging BP-funded research at Princeton University suggests that hydrogen production may ultimately be cheaper from coal than from natural gas, with permanent carbon sequestration in both cases.

[24] J. Swisher, *Clean Energy, Greener Profits: Fuel Cells as Cost-Effective Distributed Energy Resources*, in press, Rocky Mountain Institute, 2002. It will be available at www.rmi.org

[25] These include Royal Dutch/Shell, BP, Arco and Texaco before their mergers, Ford, DaimlerChrysler, and General Motors.

[26] For the autumn 2001 public summary of this sophisticated biennial Group Planning exercise, see www.shell.com/files/media-en/scenarios.pdf. As further gains in efficiency and sustainable supply, including hydrogen, continue to outpace oil depletion, we and many industry strategists expect oil to become uncompetitive even at low prices before it becomes unavailable even at high prices.

[27] For an open-source chronology of key developments, see www.rmi.org/sitepages/pid414.php.

[28] We must declare an interest: RMI, our nonprofit employer, owns substantial Hypercar, Inc. equity, and one of us (ABL) holds minor stock options.

[29] It's designed to accelerate 0–60 mph in 8.2 seconds and haul a half-ton up a 44% grade. It holds five adults and up to 69 ft^3 of cargo, or two adults and two kayaks. Its superstiff body, smart active suspension, adjustable ride height, and all-wheel digitally-controlled electric traction imply sporty performance.

[30] Industry-standard simulation tools show no damage to the passenger compartment when hitting a wall head-on at 35 mph, and compliance with Federal occupant-protection standards for a 30-mph fixed-barrier crash when the concept car collides head-on with a car twice its mass, each going 30 mph.

[31] A.B. Lovins & B.D. Williams, "A Strategy for the Hydrogen Transition," National Hydrogen Association, April 1999, www.rmi.org/images/other/HC-StrategyHCTrans.pdf, describes a transitional sequence that is profitable (≥10%/y aftertax real return) at each step, starting now. This approach is now being rapidly adopted by major energy and automotive firms. The plug-in-cars step is just one of several elements of the strategy. Studies by several other groups have recently confirmed its economic attractiveness.

[32] The hydrogen would typically be made onsite from natural gas. Some misinformed commentators have nonetheless focused on a minor alternative—splitting water with cheap offpeak electricity—to claim that we're promoting a perpetual-motion machine when a fuel cell turns the resulting hydrogen back into electricity. In

fact, despite the inevitable losses with each energy conversion, this arrangement can still make money, for two main reasons: the power plants displaced by the fuel cell's output are severalfold less efficient than those that make the offpeak electricity, and the waste heat captured from the fuel cell and its hydrogen appliance can usually displace furnace and boiler fuel, plus power generation to run air conditioners.

[33] For a concise but incomplete digest, see Hawken *et al.*, *op. cit. supra*, Chapter 2, second half.

[34] Eight currently neglected classes of policy instruments for accelerating energy efficiency are described by A.B. Lovins's 12 June 2001 keynote presentation to the European Council for an Energy-Efficient Economy, www.rmi.org/images/other-S-ECEEE8FoldWay.pdf. Expanding the policy portfolio from two categories (price and regulation) to ten should make its execution faster and surer.

[35] H. Harvey & D. Arbess, *Security Without War*, Westview (Boulder), 1993; J.J. Romm, *Defining National Security: The Nonmilitary Aspects*, Council on Foreign Relations (NY), 1993; M.T. Klare, *Resource Wars*, Metropolitan/Henry Holt (NY), 2001.

[36] A.B. Lovins & A. Gadgil, "The Negawatt Revolution: Electric Efficiency for Asian Development," Rocky Mountain Institute Publication #E91-23, 1991. Capital intensity is typically about a thousand times lower for making such electricity-saving devices than for expanding power plants and grids, and the money is repaid about ten times as fast, so the product of intensity times velocity yields a ~10,000-fold advantage. The electric power sector consumes up to a fourth of global development capital, most of it now wasted.

[37] Many have already made major energy savings simply because efficiency costs less than fuel; see examples cited at www.cool-companies.org. Among the more striking efforts by global firms, DuPont expects in this decade to increase revenue 6 percent a year, raise energy productivity at least that fast, get a third of its raw materials and a tenth of its energy from renewable sources, and cut its greenhouse gas emissions to 65% below the 1990 level. STMicroelectronics, the world's #4 chipmaker, has a set a goal of *zero* net carbon emissions by 2010, when it expects to make 40 times as many chips as it made in 1990. These environmental benefits are being pursued chiefly because they create impressive shareholder value, and not only via lower energy bills: typically the factories also work better and are quicker and cheaper to build.

[38] U.S. Energy Information Administration, *Annual Energy Review 2000*. The most important single cause is China's dramatic reduction in coal-burning since 1996 as emphasis shifts to efficiency, natural gas, and renewables. (During 1996–2000, world coal consumption fell by 7%; four-fifths of that drop occurred in China.) Global estimates for 2000 are not been clear, as China and the U.S. have a two-year reporting lag.

[39] Sound economics requires that "cost" reflect full social cost. Such internalization can be important for long-term, irreversible, or widespread effects such as toxicity, climate change, and land-use. However, for routine local side-effects, the cheapest options even in the narrowest terms of private internal cost are also often the best for society and the environment too, so internalization often wouldn't change the decision.